# [eRD29] Precision Timing Silicon Detectors for a Combined PID and Tracking System at EIC

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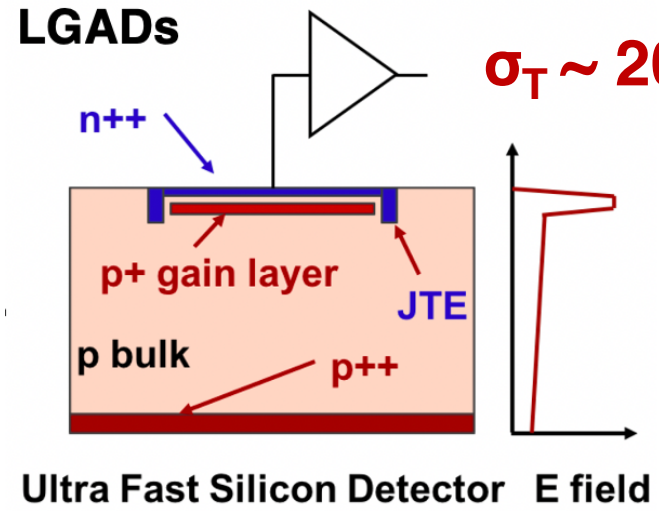
BNL EIC Detector R&D Meeting
March 26, 2020

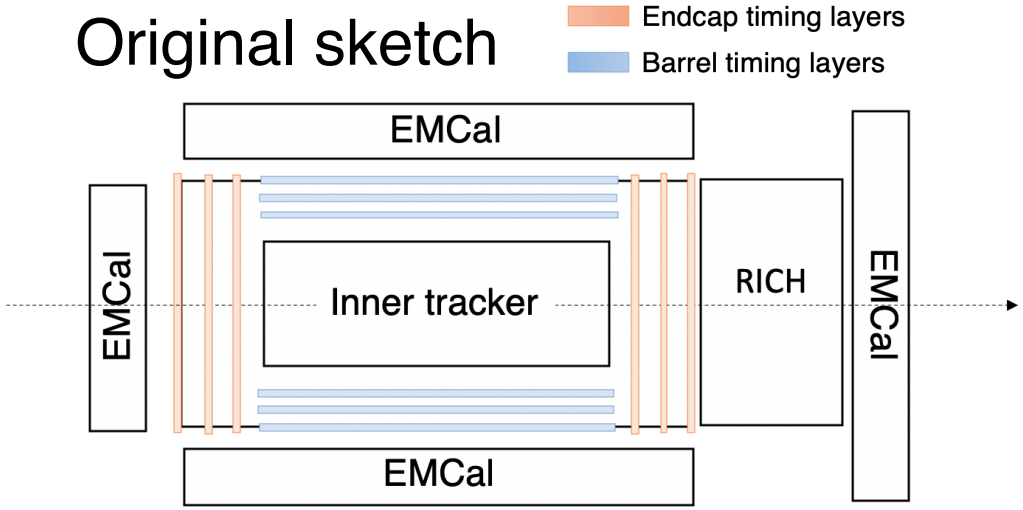
# Outline

- Recap of project goals
- Report of progress to date
- Assessment of readiness for a full TDR

# Recap of project goals

Develop high-precision timing layers based on LGADs for simultaneous TOF and (outer) tracking measurements



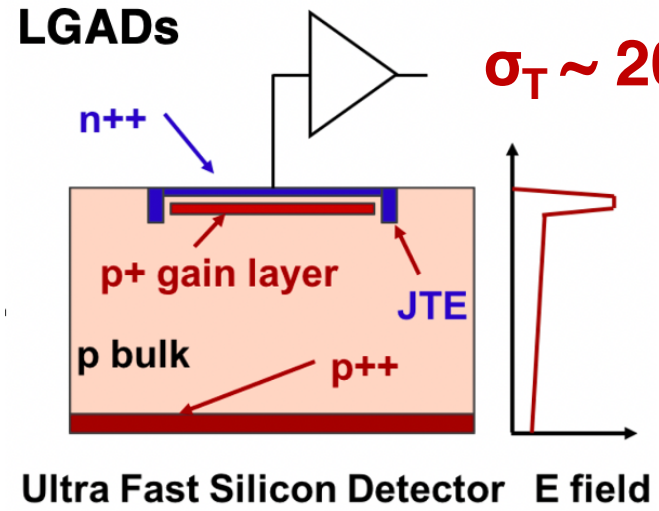



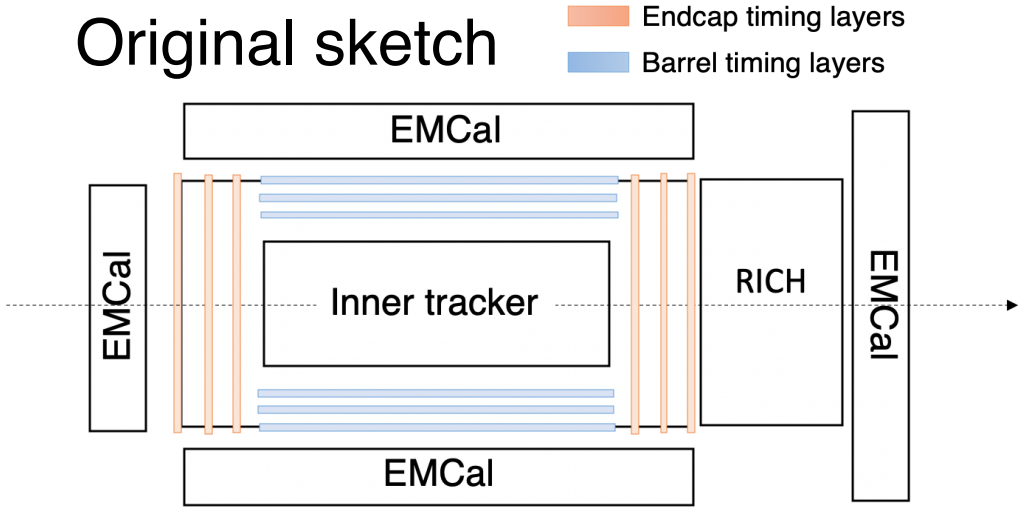

A new project started last Oct., planned deliverables:

1) R&D of ultra-thin LGADs (10/2020–03/2021)
2) Simulations of a LGADs TOF-tracker (10/2020–05/2021)
3) R&D of TI- and AC-LGADs (03/2021–09/2021)

# Recap of project goals

Develop high-precision timing layers based on LGADs for simultaneous TOF and (outer) tracking measurements




Adjusted plan:

1) **Simulations of a LGADs TOF-tracker (10/2020–03/2021)** ✓
2) R&D of ultra-thin standard and AC-LGADs (03/2021–09/2021)

(slow in acquiring sensors and difficult for lab work due to COVID)

# LGADs consortium – per recommendation of the committee

## – collaborative efforts on application of ultra-fast silicon for future HEP/NP detectors

- **EOI for EIC as a first cornerstone (LINK)**
  - 14 Institutes: ANL, BNL, OMEGA, FNAL, IFJ PAN, IJLAB, LANL, MIT, ORNL, Rice, Stonybrook, UCSC, UIC, KU
- **Interests in different detector concepts**
  - TOF, (4D) Tracker, Roman Pots, Preshower
- **Organize by areas of expertise/interest**
  - Physics Performance and Design
  - Silicon sensors
  - Front-end Electronics
  - System Design, Mechanics and Engineering
- **Meetings:** https://indico.bnl.gov/category/323/

Expression of Interest (EOI): LINK
Fast timing silicon detectors for EIC detectors

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- Argonne National Lab (ANL)
- Brookhaven National Lab (BNL)
- Organisation de Micro-Électronique Générale Avancée (OMEGA), Ecole Polytechnique
- Fermi National Lab (FNAL)
- Institute of Nuclear Physics Polish Academy of Sciences (IFJ PAN)
- Laboratoire de Physique des 2 Infinis Irène Joliot Curie (IJCLAB)
- Los Alamos National Lab (LANL)
- Massachusetts Institute of Technology (MIT)
- Oak Ridge National Lab (ORNL)
- Rice University (Rice)
- Stonybrook University (Stonybrook)
- University of California, Santa Cruz (UCSC)
- University of Illinois, Chicago (UIC)
- University of Kansas (KU)

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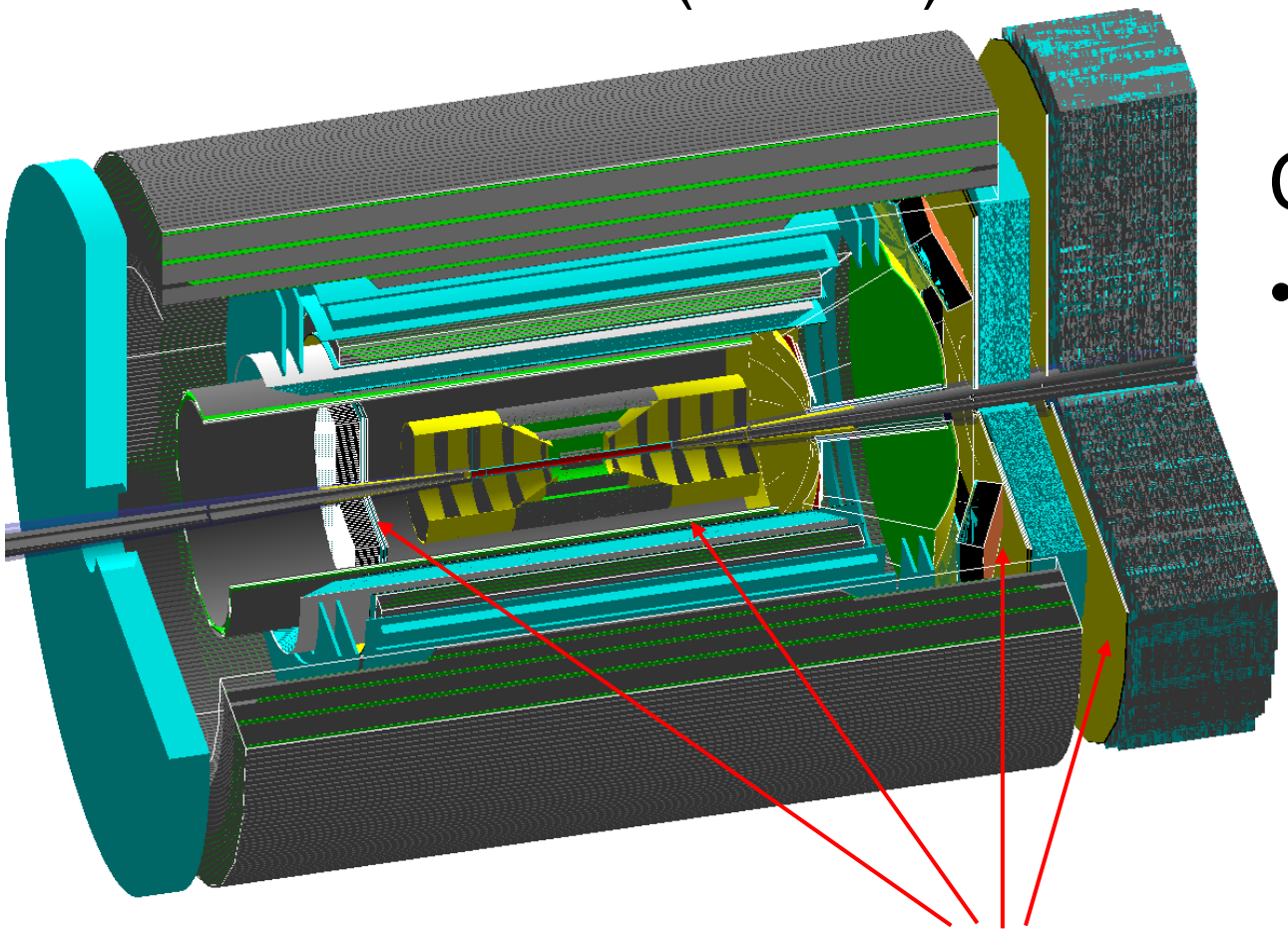
# PID and tracking with LGADs for EIC

Detector simulations (Fun4all)



General design considerations:

- Placed as far away as possible
  - Behind dRICH
  - In front or after ECAL

LGADs timing layers implemented over the full phase space

# PID and tracking with LGADs for EIC

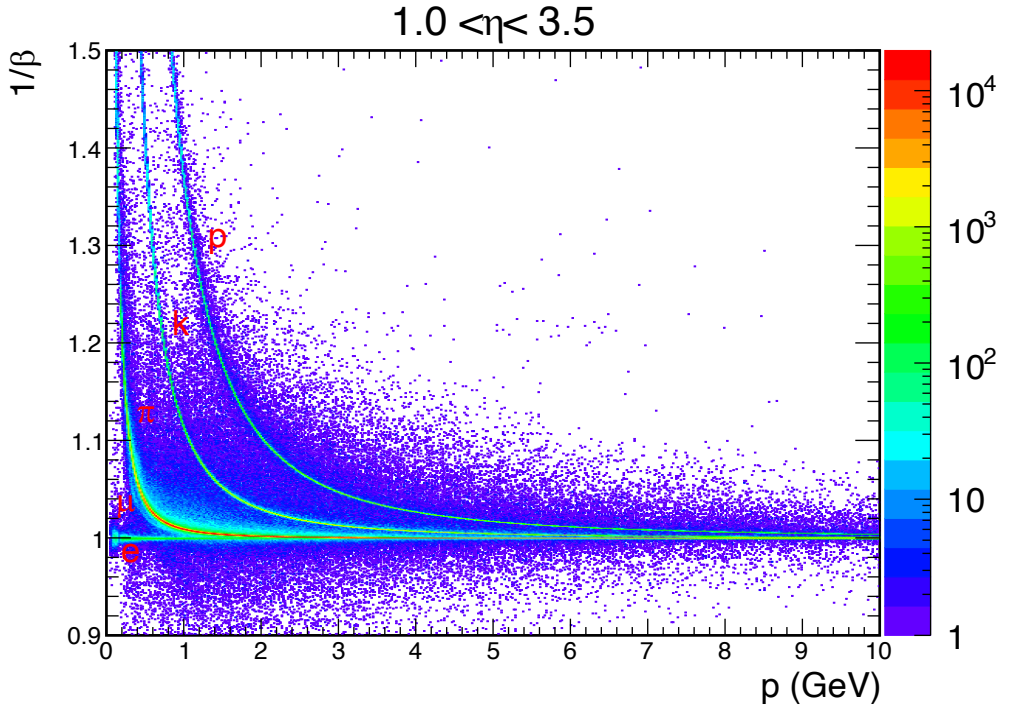
## Design details:

| | Default | $R_{barrel}$ | Length | z location | $R_{endcap,in}$ | $R_{endcap,out}$ | $\eta$ coverage | Area ($m^2$) |
|---|---|---|---|---|---|---|---|---|
| Backward | $ETTL_0$ | | | -1.555 | 0.077 | 0.632 | [-3.7,-1.6] | 1.23 |
| | $ETTL_1$ | | | -1.585 | 0.078 | 0.62 | [-3.7,-1.6] | 1.19 |
| Central | $CTTL_0$ | 0.92 | 3.6 | | | | [-1.34,1.34] | 20.8 |
| | $CTTL_1$ | 1.147 | 3.6 | | | | [-1.11,1.11] | 25.9 |
| Forward | $FTTL_0$ | | | 2.87 | 0.116 | 1.527 | [1.3,3.9] | 7.28 |
| | $FTTL_1$ | | | 2.89 | 0.117 | 1.538 | [1.3,3.9] | 7.39 |
| | $FTTL_2$ | | | 3.4 | 0.138 | 2.185 | [1.1,3.9] | 14.94 |
| Default setup: $ETTL_0 + ETTL_1 + CTTL_0 + CTTL_1 + FTTL_0 + FTTL_1 + FTTL_2$ | | | | | | | aggressive | 78.73 |
| Alternative 1: $ETTL_0 + ETTL_1 + CTTL_1 + FTTL_0 + FTTL_2$ | | | | | | | | 50.54 |
| Alternative 2: $ETTL_0 + ETTL_1 + CTTL_0 + FTTL_0 + FTTL_1$ | | | | | | | baseline | 37.89 |

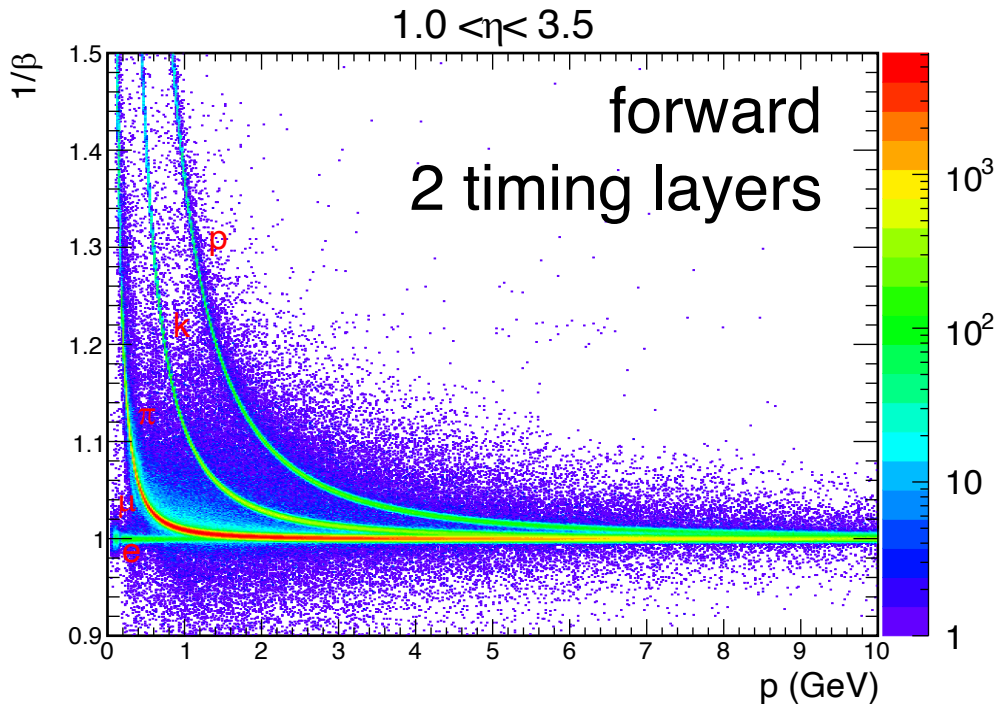
Each ETT, CTT, FTT layer can all be independently built

# PID with LGADs for EIC

With L uncer. only




With L and TOF uncer. (including $T_0$)



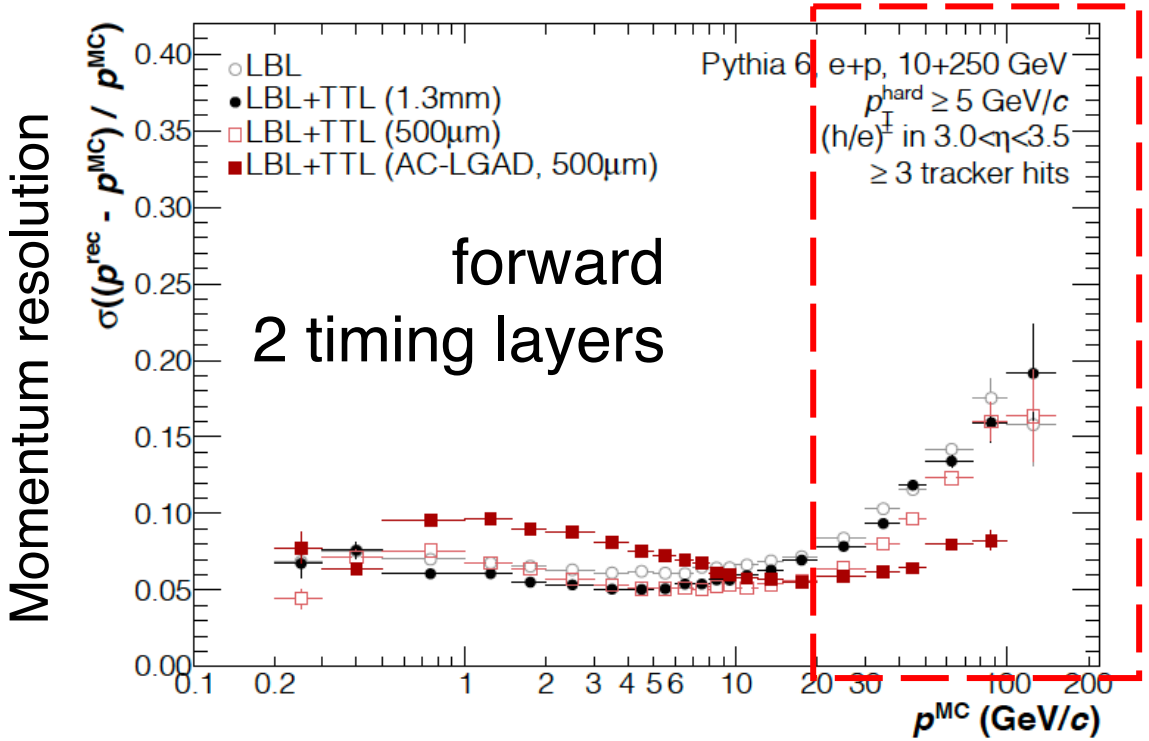

*p* range: 0.1-8 GeV

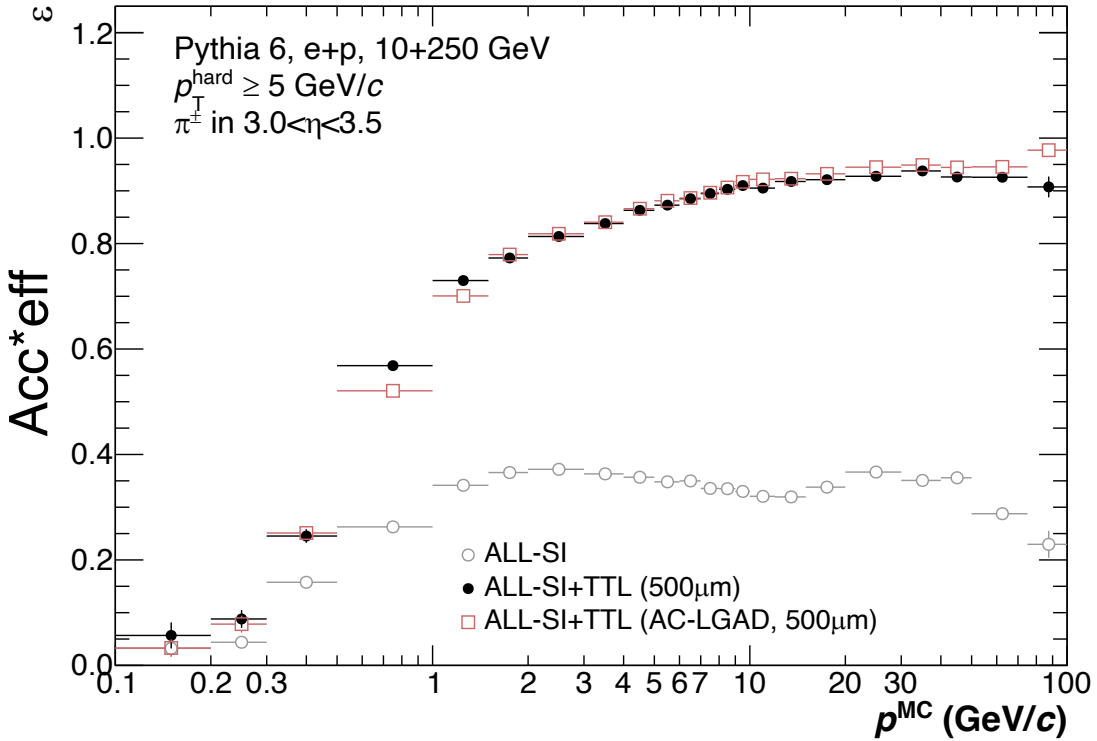
More details in the report

Together with dRICH, LGADs layers will cover PID over full *p* range for EIC, together with RICH

# Tracking with LGADs for EIC

Tracking w/o vs. w/ LGADs layers




More details in the report

LGADs layers will serve as outer tracker to improve *p* resolution by up to 50% at 100 GeV/c and efficiency at forward y

# PID and tracking with LGADs for EIC

Main lessons from comprehensive simulations:

- **LGADs can provide TOF and tracking simultaneously!**
- 1-2 layers placed as far as possible, behind RHIC detectors
- Time resolution of ~ 20 ps to cover from low (0.1 GeV/c) to intermediate (GeV/c) *p* range.
- Position resolution: ~ 30 μm to improve high p resolution by up to 50% at 100 GeV/c
- AC-LGADs with a pitch size of 0.5 mm and thickness of ~ 20-25 μm appears to the best option going forward

Expect to complete thin sensor R&Ds in the 2nd half of FY21 as COVID-19 situation improves (seems promising …)

# Beyond FY21 toward TDR

**Assessment of technological readiness:**

- LGADs is a mature technology that is being applied the upgrade of CMS and ATLAS timing layers for the high-luminosity LHC program, which faces much bigger challenges in radiation damage.
- For EIC, the technology needs to be optimized with targeted R&Ds, for specific requirements of PID and tracking momentum resolution (thinner active area, finer granularity, more power-efficient electronics, overall material budget etc.)

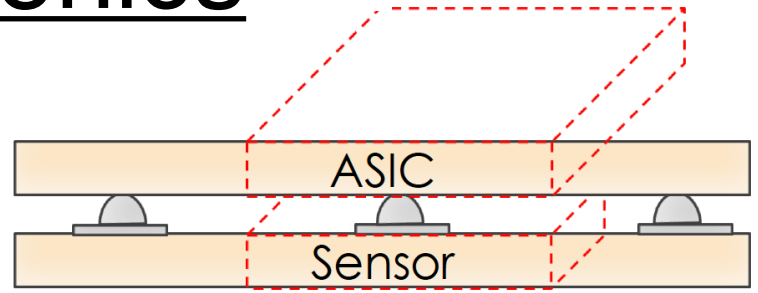
# Beyond FY21 toward TDR

**Elements to be built for a full TDR:**

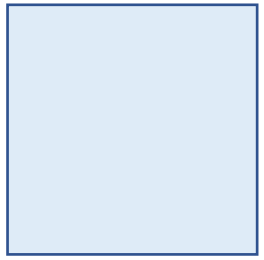
- ✓ **Readiness of LGADs sensors (to achieve in eRD29)**
- On detector electronics (ASICs)
- Modules (including power supplies, service electronics)
- Mechanical engineering, integration, installation
- Service (power system, cooling etc.)
- Data path, rates; Slow control, monitoring

Will address these together with the consortium

# On-detector electronics




**CMS/ATLAS:**



**EIC:**

| Pitch size | 1.3x1.3 mm$^2$ | 0.5x0.5 mm$^2$ |
|---|---|---|

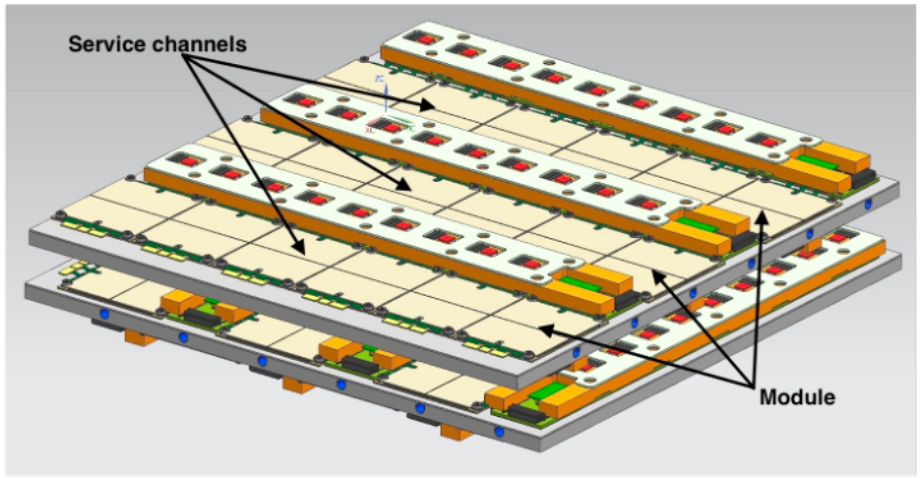
should fit in

Two possibilities:

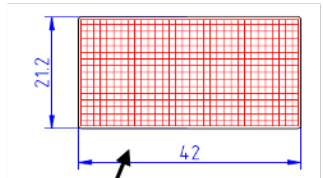
- ALTIROC (ATLAS): 130nm TDC, currently adopted by RP (eRD24)
- ETROC (CMS): 65nm TDC, more power-saving

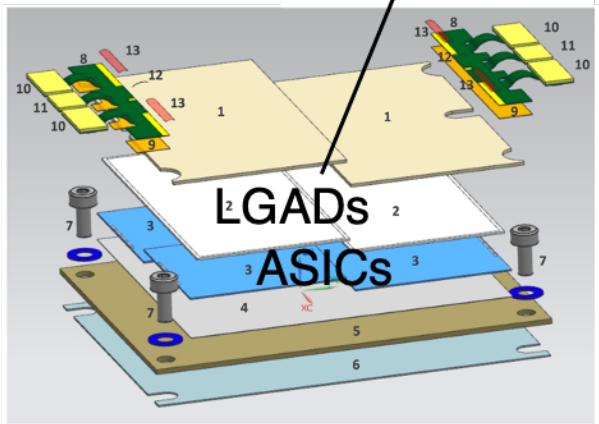
# Modules and mechanics

## Copy CMS ETL designs to the 1st order

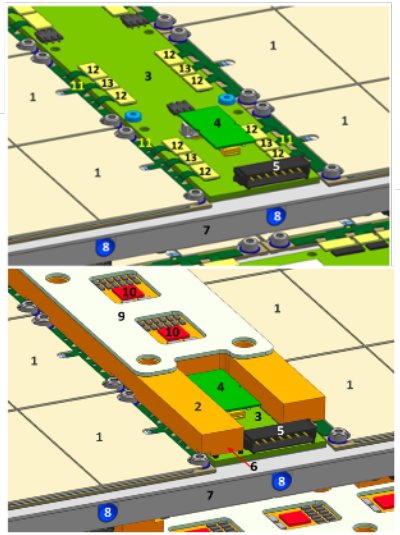



16x32 pads
(2x4 cm²)

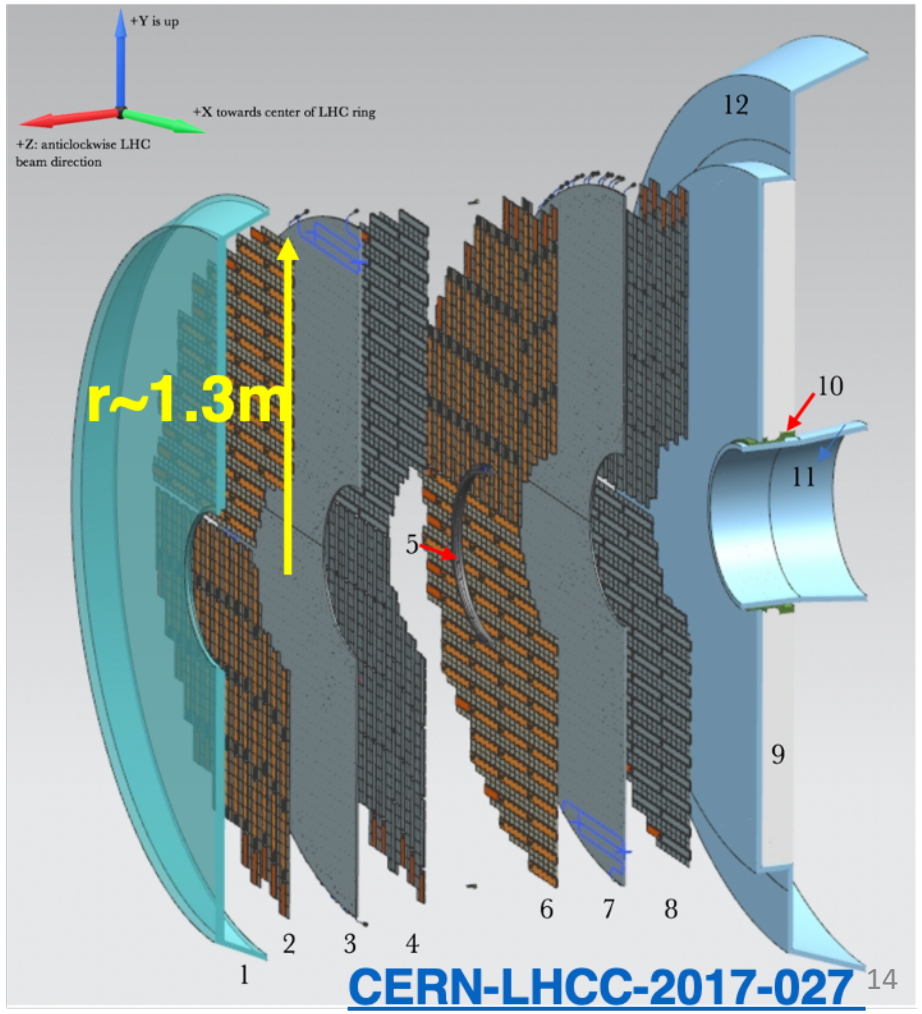



Service hybrids



## Mounted on Al plates with $C0_2$ cooling inside



# Service: power and cooling

CMS ETL power budget (per endcap):

| Component | Power (kW) |
|---|---|
| Sensor | 0.8 |
| ETROC | 12.5 |
| lpGBT | 0.6 |
| VTRx+ | 0.3 |
| DC-DC | 7.5 |
| GBT-SCA | 0.2 |
| Power cables | 2.7 |
| Heating foils | 1.0 |
| Total | 26 |

Dominated by ASICs and DC-DC

- ~2–2.5 mW per ASIC channel for occupancy ~ 10%

At EIC, much lower occupancy → lower power per channel but there are a lot more channels because of the finer pitch. More detailed estimation is needed.

# Cost assessment and schedule

~ 2.5 FTEs toward a full TDR and prototyping in 2-3 years

e.g.,

| Items | FY22 | FY23 | FY24 |
|---|---|---|---|
| Electronics design/prototyping | 1 | 1 | 1 |
| Sensor optimization | 1 | 1 | 0.5 |
| Module, mechanics, service | 0.5 | 0.5 | 1 |

# Summary

Simulation studies provided key guidance on the detector design/specs to meet performance requirements

LGADs provide an excellent option for TOF and outer tracking layers that is compact, radiation-hard, B-tolerant

Readiness for EIC: LGADs technology is mature but requires optimization to meet EIC requirements

Toward a TDR: still a lot of work needed but expertise established by the consortium. More funding needed …

# Backups